

USE OF THE C¹⁴ ISOTOPE FOR THE STUDY OF THE DECOMPOSITION OF ORGANIC MATTER IN SOIL¹

K. I. CHEKALOV and V. P. ILLYUVIYEVA, Northwestern Agricultural Scientific-Research Institute

The problem of the role of water-soluble organic substances in the formation of humic compounds in podzolic soils must be studied not only from the theoretical, but also from the practical point of view. This would shed some light on the role of individual groups of organic substances and would permit resolution of the problem of which of these must be added to the soil with organic fertilizers. We assume that organic fertilizers must contain enough water-soluble organic substances which would readily change into more complex compounds and have an important influence on humus formation upon entering into the soil. It is quite probable that the decrease in humus content reported in a number of Russian and foreign papers is associated with the use of organic fertilizers containing a very small amount of water-soluble organic compounds. Such organic fertilizers include peat which is frequently used without previous composting resulting in that water-soluble organic substances are hardly supplied with it to the soil.

There was a time when many investigators believed that water-soluble organic substances from plant residues are the primary source of the formation of soil humus. But there is no proof of the correctness of these views, primarily because of the absence of direct methods which would allow tracing the modification of water-soluble compounds during individual stages of the formation of soil humus.

We used C¹⁴ to study the role of water-soluble organic substances in the formation of humic soil compounds.

Method of study. Clover was grown in the greenhouse in special 1 x 1 m glazed boxes 0.6 m high and filled with soil. During bloomstage the box with the soil was hermetically closed from above by a second box of the same dimensions and with glass walls. Before the box was closed sodium carbonate tagged with C¹⁴ was added in a porcelain cup on a special stand. Three openings were made in the ceiling of the glassed-in box (chamber). A separatory funnel was inserted in one of the openings. Through it lactic acid was poured dropwise into the porcelain cup to decompose the sodium carbonate so that carbon dioxide tagged with C¹⁴ went into

the atmosphere. A fan was mounted in the other opening to distribute the carbon dioxide uniformly in the chamber. A glass tube was inserted into the third hole in order to draw off the excess carbon dioxide and to neutralize it with an alkaline liquid at the end of the experiment.

In 1958 carbon dioxide was added into the chamber with clover in very cloudy weather and it was feared that its assimilation by the plants would be difficult, especially since the chamber was saturated only one day. But this time proved to be sufficient for the radioactive carbon to enter the plant cells. In 1959 the chamber was saturated with C¹⁴ in clear weather and the clover remained in the box saturated with carbon dioxide one day. Then the excess carbon dioxide was drawn off into a flask with an alkaline solution, the glassed-in portion of the box was removed, and the clover was cut and dried. Samples were taken from its dry pulverized mass and the water-soluble part and the hydrolyzable part were removed successively with 0.5 N H₂SO₄, as well as the fraction soluble in 0.1 N NaOH.

Separate fractions of organic matter were extracted from clover in the following manner. Five hundred milliliters of water were added to a 100-g sample of dry clover and the whole was steeped for 5 hours in a heated water bath. The clarified liquid was poured into a volumetric flask the following day. The clover was treated again with 500 ml of water, heated for 5 hours in a water bath, allowed to settle, and poured off, etc. A total of 3500 ml of liquid was collected. The collected liquid containing the water-soluble part of the organic matter was evaporated to 250 ml. The remaining undissolved part of the clover was subjected to hydrolysis by 250 ml of 0.5 N H₂SO₄ in the cold for 42 hours. After hydrolysis the mass was transferred into a Büchner funnel and washed with water until all traces of SO₄ had disappeared from the wash water. The non-hydrolyzable part of the clover was divided into two parts. One part was dried at 80°C and the other part was subjected to further treatment with 0.1 N NaOH for 2 hours in a boiling water bath. After the treatment the mass was transferred to a Büchner funnel and washed with hot water until the reaction of the wash water was neutral. Successive treatment of clover hay with the foregoing diluents yielded the following organic

¹ The work was conducted in 1958-1960 at the fertilizer laboratory of the Northwestern Scientific-Research Institute of Agriculture.

USE OF C¹⁴ ISOTOPE FOR STUDY OF DECOMPOSITION OF ORGANIC MATTER

material: a) with the water-soluble fraction removed; b) the water-soluble part; c) the clover fraction lacking water-soluble compounds and compounds hydrolyzable in 0.5 N H₂SO₄; and d) the clover fraction lacking compounds soluble in water, acid, and alkali.

To study the decomposition and synthesis of organic matter, the variously prepared clover mass was added to the soil. Twenty-five grams of clover were added to 250 g of soil. The rest of the material was added to the soil in amounts which remained from the 25 g of clover after the corresponding treatments with the above diluents. Thus, to 250 g of soil were added (in grams):

	In 1958	In 1959
Clover	25.0	25.0
Clover deprived of the water-soluble part	18.3	16.6
Clover deprived of water-soluble and hydrolyzable compounds	14.6	13.8
Clover deprived of water-soluble hydrolyzable compounds and compounds soluble in alkali	9.1	12.0
Water-soluble part of clover	13.4 (in a double amount)	8.4

The 1958 and 1959 experiments on the decomposition of organic matter in soil lasted for three months and were replicated three times according to the following scheme: 1) soil; 2) soil to which 10% by weight of the clover mass was added (dry substance); 3) soil with the clover mass deprived of the water-soluble part; 4) soils with the clover mass from which the water-soluble and hydrolyzable parts were removed; and 5) soil with the clover mass deprived of the water-soluble and hydrolyzable parts, and the part soluble in alkali.

In 1958 experiments were made with coarse clay loam weakly podzolized, and slightly cultivated soil; and in 1959, with a fine clay loam weakly podzolized, and slightly cultivated soil. During the entire experiment soil moisture in the pots was maintained at 60% of field capacity and at a temperature of 200-250°C.

After three months the soil was dried and subjected to fractional analysis of organic matter by Tyurin's method.

The C¹⁴ content in the plant material and soils was determined in the various treatments of the experiment by means of an MST-17 end-type counter. The samples of dry material were 0.02 g. During determination of C¹⁴ in solutions the volume of the liquid varied from 5-0.5 ml, depending on their specific gravity. The solution was evaporated on a weighed dish and then the dish was weighed again. A corresponding correction was introduced for self-absorption according to Tselishchev's curve [2].

In addition to the correction for self-

absorption, other corrections were introduced for background and the resolution time of the counter. Activity was expressed in counts per minute per gram of initial substance. Observations for the total and fractions containing carbon in soil were taken at the moment of setting up the laboratory experiment, after 10 days and after 3 months.

Experiments of 1958. Data on the fractional distribution of carbon are presented in Table 1.

The addition to the soil of clover hay treated with various extractants resulted in a sharp increase in carbon content. At the start of the experiment the largest amount of carbon was found in the soil with nontreated clover; and the least amount, in the soil with clover hay successively treated with water, acid, and alkali. The addition of the water-soluble part of clover to the soil resulted in a 50% increase of its carbon content. After three months decomposition of clover of a qualitatively different composition, the total content of organic matter decreased in all composts, the greatest decrease being recorded for soil to which nontreated clover, the water-soluble part of clover, and clover deprived of its water-soluble part were added, i.e., in those soil samples to which clover hay with the highest content of mobile forms of organic matter was added. The least amount of carbon was lost from the soil to which clover hay deprived of water-soluble, and readily hydrolyzable substances, and substances soluble in alkali was added. The highest content of carbon in the water extract was observed at the end of composting in the soil to which the water-soluble part of the clover was added. The carbon content in the water-soluble fraction increased by a factor of three in the soil with clover as compared to the control, while in the soil with the water-soluble part of clover the carbon content in the same fraction increased by a factor of more than five. It must be noted that the carbon content in the fraction hydrolyzable with acids was also highest in soil to which the water-soluble part of clover was added. Obviously, the addition of water-soluble organic matter, i.e., the biologically most active part, resulted in a slight instability of the complex of organic compounds hydrolyzable with acids. The water-soluble part proved to be a "biocatalyst" here for the less readily decomposed compounds of the organic matter of clover.

Observations of the behavior of the radioactive carbon during analysis of individual fractions of organic matter showed even more clearly the role of the water-soluble part of clover added to the soil.

Table 2 gives the content of total and radioactive carbon prior to the addition of clover hay into the soil in the 1958 experiment.

The highest specific carbon activity is observed in the water-soluble part of clover; it is higher than in the nontreated clover hay by a factor of almost 2.5. Table 3 gives data on the activity of carbon in the composts, at the beginning of the 1958 experiment and three months after the decomposition of the organic matter of clover in a fine-textured soil.

Table 1

Carbon content in individual fractions of organic matter in the soil, % of dry matter

Experimental treatment	C content					
	At the beginning of the experiment	After 3 months of composting				
		Total amount	Fractions			Residue after all treatments
			Water-soluble	Hydrolyzable	Alkaline	
Soil	4,02	4,02	0,046	0,110	1,66	2,20
" + 10% clover	7,82	5,41	0,134	0,143	2,02	3,11
" + clover after removal of water-soluble part	7,02	5,34	0,083	0,118	1,87	3,27
" + clover deprived of hydrolyzable compounds	6,71	5,57	0,086	0,113	1,91	3,46
" + clover deprived of water-soluble, readily hydrolyzable and alkali-soluble compounds	5,27	4,84	0,086	0,116	1,78	2,86
" with the water-soluble part of clover added	6,03	4,39	0,236	0,149	1,58	2,43

Note: Comma represents decimal point.

Table 2

Content of total carbon and C^{14} in clover hay (dry substance)

Experimental treatment	C content, % of dry clover	Count per minute per 1 g of dry mass	Specific C activity
		Thousands	
Clover hay	42,6	403	946
Clover hay deprived of the water-soluble part	44,0	338	769
Hay after removal of compounds hydrolyzable with 0.5 N H_2SO_4	46,1	319	693
Hay after removal of compounds soluble in 0.1 N NaOH	41,3	290	702
Water-soluble part of clover hay	7,1	154	2156

The data demonstrate the role of individual fractions of organic matter in the formation of humic substances in the soil. These data can be examined more easily in Table 4 where they are presented in percentages of total C^{14} in the initial soils and after three months of composting.

Even though the absolute amount of radioactive carbon after three months of composting was found to be highest in the soil with clover, while it was least in the soil with the water-soluble part of clover, the maximum amount of radioactive carbon during the removal of organic substances in an alkaline extract was observed in the soil to which the water-soluble part of

clover was added. This maximum in the soil with the water-soluble part of clover was due to the high C^{14} content in the group of fulvic acids.

Thus, the determination of C^{14} in soils in the 1958 experiment shows that the highest content of humic acids is to be found in soils with the highest content of water-soluble organic matter. This can be seen even more clearly upon examination of the distribution of C^{14} by fractions of organic matter during successive soil treatments with various extractants (Table 5). These data demonstrate the active role of the water-soluble part of clover in the formation of humic substances, which role not only influences the content

USE OF C¹⁴ ISOTOPE FOR STUDY OF DECOMPOSITION OF ORGANIC MATTER

Table 3

Carbon activity in the composts and its distribution in the group of organic compounds removed from the soil by the alkali extract (in thousands of counts per minute per gram of soil)

Experimental treatment	In the soil		In the alkali extract	
	At the beginning of comp.	After 3 mths. of storage	Fulvic acid group	Ulmic acid group
Soil + clover	40.4	20.4	5.7	2.5
" + clover deprived of the water-soluble part	23.1	13.9	3.0	1.7
" + clover deprived of compounds hydrolyzable with acids	17.7	13.3	4.9	1.1
" clover deprived of the alkali-soluble part	8.7	6.2	1.4	0.6
" + water-soluble part of clover	35.3	12.9	6.6	1.9

Note: During analysis each compost was checked six times and each sample, 8 times.

Table 4

Distribution of C¹⁴ by organic matter fractions

Experimental treatment	C ¹⁴ in % of its total content in the initial soils			C ¹⁴ in % of its total content in soil at end of experiment		
	Fulvic acid group	Ulmic acid group	Total	Fulvic acid group	Ulmic acid group	Total
Soil + clover	14.3	6.3	20.6	28.3	12.4	40.7
" + clover deprived of the water-soluble part	13.0	7.4	20.4	21.5	12.2	33.7
" + clover deprived of compounds hydrolyzable with acids	28.1	6.3	34.4	37.4	8.4	45.8
" + clover deprived of the alkali-soluble part	16.0	6.8	22.8	22.4	9.5	31.9
" + water-soluble part of clover	18.9	5.5	24.4	51.6	15.0	66.6

of humic substances entering the soil water extract, but is also noticeable in the group of compounds extracted with 0.5 N sulfuric acid and even with 0.1 N alkali.

Proceeding from the activity of tagged carbon, shown in Table 5, we have calculated its distribution by individual fractions of organic matter in percentages of the initial content of the isotope in the composts. Data in Table 6 show that the carbon isotope added to the water-soluble part of clover is distributed among all the fractions of organic matter. Even in the group of non-hydrolyzable compounds its content exceeds 25% of the initial amount.

Thus, direct observations of radioactive carbon have demonstrated that water-soluble organic substances added to fine-textured soil synthesize into complex compounds during decomposition and actively participate in the creation of substances called humic acids.

Experiments of 1959. Total carbon content showed the same pattern as in the 1958 experiment (Table 7) when clover (treated in different ways) was added to coarse-textured soil. The fact that after ten days of decomposition the

greatest carbon losses were found in soil to which clover with its water-soluble part was added is striking. After three months of decomposition carbon losses increased in all soils, except that soil to which the water-soluble part of clover was added. The same data show that upon further transformation of organic matter, the water-soluble part of clover produces an increase of even alkali-soluble and non-hydrolyzable compounds.

If the amount of carbon in each fraction of organic matter is expressed in percentages of the total carbon content (in each treatment) then it seems that the water-soluble compounds of clover have promoted most conservation of organic matter in the hydrolyzable and alkali-soluble fractions of the soil (Table 8).

Observations of the radioactivity of C¹⁴ in the individual fractions were made at various periods of decomposition of organic matter in the soil (Table 9).

On the whole, C¹⁴ activity decreases with time in all the materials. The sharpest decrease is observed in the soil to which the water-soluble part of clover was added and a less sharp

Table 5

Total content of radioactive carbon in individual fractions of organic matter after 3 months of decomposition in the soil

Experimental treatment	Successive treatment											
	With water			0,5 n H ₂ SO ₄			0,1 n NaOH			Non-hydrolyzable residue		
	Counts/ min/g of soil	C. %	Specific C activity, thousands	Counts/ min/g of soil	C. %	Specific C activity, thousands	Counts/ min/g of soil	C. %	Specific C activity, thousands	Counts/ min/g of soil	C. %	Specific C activity, thousands
Soil	—	0,134	—	—	0,110	—	—	1,786	—	—	2,02	—
" + 10% clover	1251	0,151	828	995	0,138	721	5441	1,928	282	12615	3,79	332
" + clover without the water-soluble part	279	0,090	310	253	0,115	220	3142	1,888	166	10075	3,89	259
" + clover without the hydrolyzable part	257	0,086	298	267	0,113	236	2965	1,912	155	9844	3,35	293
" + clover after treatment with alkali	139	0,089	156	833	0,116	718	1245	1,781	70	4038	2,95	136
" + water-soluble part of clover	2503	0,226	1107	1467	0,156	940	4041	1,707	236	2967	2,52	117

Note: Comma represents decimal point.

Table 6

Activity of C¹⁴ (in counts/min) at the end of the experiment in individual fractions, % of total activity of organic matter

Experimental treatment	Distribution of C ¹⁴ , %			
	Fractions			
	Water-soluble	Readily hydrolyzable	Alkali	Residue after all treatments
Soil + clover	6,1	4,90	26,7	62,1
" + clover with the water-soluble part	2,0	1,8	22,8	73,2
" + clover without hydrolyzable compounds	1,9	2,0	22,2	73,8
" + clover after treatment with alkali	2,2	13,3	19,9	64,5
" + water-soluble part of clover	22,7	13,3	36,8	27,0

Note: Comma represents decimal point.

Table 7

Carbon content and distribution by fractions of organic matter after periods of storage, % of absolutely dry material

Experimental treatment	C content in the soil	C content			
		Fractions			
		Water-soluble	Hydrolyzable (0.5 N H ₂ SO ₄)	Alkali-soluble (0.1 N NaOH)	Residue after all treatments
First period (at the beginning of experiment)					
Soil	1,37	0,030	0,105	0,468	0,76
" + clover	4,88	0,734	0,239	0,820	3,08
" + clover without the water-soluble part	4,16	0,113	0,148	0,809	3,08
" + clover without hydrolyzable compounds	3,56	0,054	0,113	0,827	2,60
" + clover without alkali-soluble compounds	2,78	0,056	0,147	0,638	1,94
" + water-soluble part of clover	2,34	0,820	0,184	0,562	0,77
Second period (10 days later)					
Soil	1,33	0,091	0,119	0,464	0,65
" + clover	3,74	0,338	0,240	0,768	2,39
" + clover without the water-soluble part	3,50	0,241	0,208	0,732	2,31
" + clover without hydrolyzable compounds	3,24	0,186	0,198	0,667	2,19
" + clover without alkali-soluble compounds	2,99	0,172	0,157	0,620	2,04
" + water-soluble part of clover	1,79	0,251	0,160	0,587	0,78
Third period (3 months later)					
Soil	1,40	0,053	0,103	0,584	0,66
" + clover	3,10	0,178	0,170	0,753	1,99
" + clover without the water-soluble part	2,99	0,102	0,116	0,885	1,94
" + clover without hydrolyzable compounds	3,02	0,095	0,138	0,785	2,00
" + clover without alkali-soluble compounds	2,70	0,103	0,147	0,683	1,76
" + water-soluble part of clover	1,77	0,154	0,162	0,620	0,83

Note: Comma represents decimal point.

decrease is observed in soil to which clover was added after acid and alkali hydrolysis. The fact that C^{14} activity remained practically unchanged after ten days in the soil to which clover after acid hydrolysis and clover treated with alkali were added is striking. The C^{14} activity also remained almost unchanged after three months of decomposition in soils to which hydrolyzed clover was added, while it decreased somewhat in the soil with clover which was treated with alkali in addition to being hydrolyzed with acid. Apparently additional treatment with alkali created conditions favorable for the decomposition (mineralization) of organic matter and to the separation of its forms which proved to be more mobile and more capable of transformation into other organic compounds.

The state of C^{14} was different in the soil to which the water-soluble part of clover was added. This soil underwent considerable change. This is most clearly seen from data on C^{14} activity in the individual fractions of organic matter. The total activity of C^{14} dropped sharply with increasing time of decomposition of the water-soluble part of clover in the soil. When the experiment was made in the non-hydrolyzable residue of soil (after all the treatments) with the water-soluble part of clover, no C^{14} was detected, but 10 days later C^{14} activity reached 1875 counts/min in this fraction of organic matter and three months later it reached 1025 counts/min. This indicates that 10 days after the addition of the water-soluble part of clover even the non-hydrolyzable fraction of organic matter of the soil was subject to biological processes and C^{14} appeared in it. It is natural to assume

that new groups of non-hydrolyzable substances formed during the transformation of water-soluble organic compounds and that these substances replenished the carbon of the non-hydrolyzable fraction. C^{14} activity was 307 counts/min in the alkaline fraction of the organic matter of soil with the water-soluble part of clover, it increased to 1228 counts/min after 10 days and amounted to 895 counts/min after three months. The appearance of C^{14} activity in the alkali-soluble fraction is evidently associated with the development of microbiological processes in the soil to which the water-soluble part of clover was added.

In summary, we can say that if the carbon isotope was not recorded in the non-hydrolyzable fraction of the initial material (soil + the water-soluble part of clover), ten days and three months later, the water-soluble part of organic matter combined with the non-hydrolyzable residue or changed into non-hydrolyzable fractions during the process of biological transformation. Hence we must conclude that the water-soluble part participates in the formation of non-readily decomposed organic soil compounds as a result of biological transformation.

We must also note the following. If C^{14} activity in the various fractions after ten days or three months of decomposition is expressed in percentages of total soil activity, then the relative activity is highest during all periods of observation in the soil with the water-soluble part of clover. This can be seen from the data in Table 10.

Table 8

Carbon content by fractions of organic matter, % of total soil carbon after 3 months of decomposition

Experimental treatment	1958				1959			
	Fractions				Fractions			
	Water-soluble	Readily hydrolyzable	Alkali-soluble	Residue	Water-soluble	Readily hydrolyzable	Alkali-Soluble	Residue
Soil	1,1	2,7	41,2	54,7	3,78	7,35	41,7	47,1
" + clover	2,5	2,7	37,3	57,5	5,74	5,48	24,2	64,4
" + clover without the water-soluble part	1,5	2,2	35,0	61,3	3,40	3,87	27,8	64,8
" + clover without hydrolyzable compounds	1,6	2,0	34,3	62,1	3,14	4,56	25,9	66,2
" + clover without alkali-soluble compounds	1,8	2,4	36,8	59,0	3,81	5,44	25,2	65,4
" + water-soluble part of clover	5,3	3,4	36,0	55,3	8,70	9,15	35,0	47,1

Note: Comma represents decimal point.

Table 9

Activity of C¹⁴ during various period of decomposition of organic matter

Experimental treatment		Activity per/g of soil, thous- ands of counts/min	Activity in thousands of pulses/min/g				Residue after treatments
			Fractions				
			Water- soluble	Hydrolyzable			
				With acid	With alkali		
At the beginning of the experiment							
Soil				None			
"	+ clover	22,9	10,9	1,9	1,6		8,2
"	+ clover without the water-soluble part	10,8	0,43	0,70	1,6		7,8
"	+ clover without the water-soluble and hydrolyzable parts	8,6	0,10	0,16	1,6		6,6
"	+ clover without the water-soluble, hydrolyzable, and alkali-soluble parts	6,0	0,08	0,15	0,30		5,4
"	+ water-soluble part of clover	12,1	11,0	0,95	0,31		None
Ten days later							
Soil				None			
"	+ clover	17,2	2,9	1,7	2,5		9,9
"	+ clover without the water-soluble part	10,3	0,65	0,78	1,1		6,9
"	+ clover without the water-soluble and hydrolyzable parts	8,6	0,40	0,49	1,1		6,5
"	+ clover without the water-soluble, hydrolyzable, and alkali-soluble parts	6,0	0,19	0,26	1,1		4,5
"	+ water-soluble part of clover	7,1	2,6	1,4	1,2		1,8
Three months later							
Soil				None			
"	+ clover	10,2	0,71	0,78	2,2		6,1
"	+ clover without the water-soluble part	8,1	0,24	0,57	1,7		5,0
"	+ clover without the water-soluble and hydrolyzable parts	8,2	0,24	0,38	1,6		5,8
"	+ clover without the water-soluble, hydrolyzable, and alkali-soluble parts	5,0	0,14	0,21	0,83		3,6
"	+ water-soluble part of clover	3,3	0,51	0,68	0,89		1,0

Note: Comma represents decimal point.

Table 10
C¹⁴ activity (pulses/min) by individual fractions, % of initial activity of organic matter

Experimental treatment	At the beginning of the experiment				After 10 days				After 3 months			
	Fractions			Residue after treatment	Fractions			Residue after treatment	Fractions			Residue after treatment
	Water-soluble	Hydrolyzable	Alkali-soluble		Water-soluble	Hydrolyzable	Alkali-soluble		Water-soluble	Hydrolyzable	Alkali-soluble	
Soil + clover	47,9	8,6	7,4	36,1	17,2	10,0	14,8	57,7	6,9	7,6	22,6	60,4
" + clover without the water-soluble part	4,0	6,4	15,0	72,8	6,3	7,6	11,0	67,3	3,0	7,0	21,1	61,3
" + clover without hydrolyzable compounds	1,2	1,8	18,7	76,8	4,6	5,8	13,3	76,0	3,0	4,7	20,5	70,8
" + clover after treatment with alkali	1,4	2,6	4,9	89,7	3,1	4,4	17,7	74,5	2,9	4,3	16,7	72,1
" + water-soluble part of clover	90,0	7,8	2,5	0,0	37,0	19,7	17,1	26,1	15,5	19,9	26,7	30,5

Note: Comma represents decimal point.

Conclusions

1. The influence of individual fractions of organic matter extracted from clover and containing tagged C¹⁴ on the formation of humic substances in two different podzolic soils was studied for two years under laboratory conditions.

2. Observations of C¹⁴ and fractional analysis of the organic matter of soil at the beginning of the experiment, and 10 days later, and 90 days later, showed that the influence of the water-soluble part of clover is not limited only to changes in the mobile forms of the organic matter of soil.

3. The radioactive carbon isotope added to soil with the water-soluble part of clover is found ten days later in all the fractions of organic matter, even in the non-hydrolyzable soil residue. This indicates that the participation of the water-soluble part in the formation of humic soil compounds is associated with the development of biological processes. Thus, direct observations of C¹⁴ have demonstrated that the water-soluble compounds of organic matter take an active part in the formation of organic soil compounds which do not readily decompose.

Received May 30, 1961

BIBLIOGRAPHY

1. ZELENSKIY, O. V., O. A. SEMIKHATOVA, and V. L. VOZNESENSKIY. 1955. Methods of using C¹⁴ for the study of photosynthesis. Izd. AN SSSR.
2. TSELISHCHEV, S. P. 1954. Some methodological problems in the use of radioactive tracers in agrobiolgy. Izv. Timiryazevsk. s.-kh. akad.
3. Trudy Vsesoyuznoy nauchno-tekhnicheskoy konferentsii po primeneniyu radioaktivnykh i stabil'nykh izotopov i izlucheniya v narodnom khozyaystve i nauke. 1958. Collection of articles Moscow, Izd. AN SSSR.